§17. Microwave Transmissiometry to Obtain Density Profile of Divertor Leg Plasmas

Ejiri, A. (Univ. Tokyo), Kawahata, K.

Microwaves are widely used in plasma diagnostics to acquire information on plasma density. Interferometry and reflectometry are now standard techniques for nonintrusive density measurement. While these measure the phase of transmitted or reflected waves, there is another class of microwave diagnostic method which do not measure the phase. Here, microwave transmissiometry, in which transmissivity is measured, is proposed and its feasibility as a density profile measurement is studied[1].

Here the principle of transmissiometry is described (Fig.1). When microwave propagates to a cutoff, the main part of the wave is reflected, because the region beyond the cutoff is an evanescent region. If the evanescent region is thin, a wave with a damped amplitude emerges from the opposite side of the region, and propagates forward. This is called the tunnel effect. Transmissivity can be represented by Gamov's penetration factor, which is a function of the density profile for ordinary-mode (O-mode) propagation. These features lead to the possibility of extracting density profile information from the transmissivity (as a function of microwave frequency).

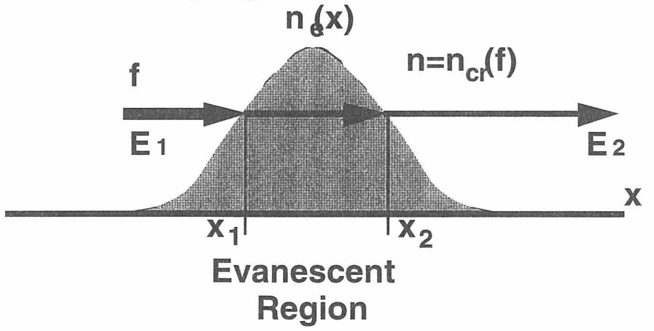

Fig.1 Schematic drawing of the microwave propagation across a sheet plasma.

In order to study the feasibility of microwave transmissiometry, we consider a one dimensional configuration with a parabolic density profile. Transmissivity and reflectivity can be calculated from the solution of one dimensional wave equations. Figure 2 shows the calculated transmissivity as a function of probing frequency for the case where $n(0)=10^{19}$ m^{-3}, a=0.01, 0.02 and 0.04 m. $n(0)$ is the central density and a is the half width of the plasma. Transmissivity increases with the frequency and becomes one for frequencies well above the cutoff frequency for the maximum density (vertical line in Fig.2). Below the cutoff frequency, transmissivity increases exponentially with the frequency. The slope becomes steeper as width a increases. In this region, the transmissivity obtained from the wave equation agrees with Gamov's penetration factor. On the other hand, they disagree at frequencies around the cutoff due to the fail in WKB approximation. Transmissivity has been calculated for various profile shape. While for a parabolic profile, transmissivity is a straight line in the semi-logarithmic scale, it is not for different profile shapes.

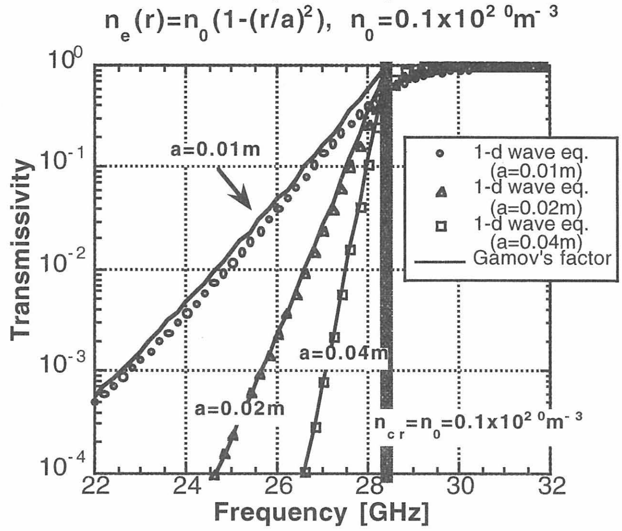

Fig.2 Transmissivity as a function of probing microwave frequency for parabolic density profiles.

The maximum density is derived from the frequency where the curve (straight line for a parabolic profile) and the flat line intersect. Information on the profile can be obtained from the slope and curvature.

Since transmissiometry uses tunnel effect it can be applied to thin plasmas. For a thick plasma, the slope below the cutoff frequency becomes very steep, so that the measurement of slope is difficult for a given dynamic range of transmissivity and for a given accuracy of frequency. A reasonable dynamic range and frequency accuracy show that the divertor leg of LHD plasma can be measured by this method.

Taransmissiometry is a very simple method to obtain information on density profile of thin plasmas. In contrast to the transmissiometry, interferometry has poor accuracy in thin plasmas, because of its short integration length, and it measures line integrated density. Furthermore, interferometry can suffer from phase changes due to mechanical vibration of the wave path and frequency drift of the microwave source.

Reference

1)A.Ejiri, K.Kawahata,Jpn. J. Appl. Phys. 39 (2000), to be published.